OPERATIONAL ACCEPTANCE TEST REPORT

for

Automated Surface Observing System (ASOS)

All-Weather Precipitation Accumulation Gauge (AWPAG)

July 2004

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service
Office of Operational Systems
Field Systems Operations Center
Test and Evaluation Branch

Introduction and Background

The All-Weather Precipitation Accumulation Gauge (AWPAG) was developed by Ott Hydrometrie of Germany and can only be installed at sites equipped with the ASOS Planned Product Improvement processor upgrade and Acquisition Control Unit (ACU) software Version (V) 2.7B or later. The AWPAG Operational Acceptance Test (OAT) was conducted at 16 sites where the processor upgrade OAT was already under way. Although most of the OAT evaluation was performed with pre-production AWPAGs, production units were installed and evaluated briefly at all 16 sites by the end of the OAT to verify their performance.

The purpose of the OAT was to confirm satisfactory integration of the AWPAG into ASOS at representative field sites and evaluate its readiness for general implementation at field sites. Since modifications to the ACU software were required to support the AWPAG, confirmation of overall ASOS performance with the revised software was an integral part of the AWPAG OAT. Although a comparison of the AWPAG to the Frise Heated Tipping Bucket Rain Gauge (HTBRG) was performed for 11 of the 16 AWPAG sites during the OAT (Appendix A), the comparison was not intended as a definitive sensor range/accuracy test. Prior to the OAT (during the winter of 2002-2003), however, qualification testing of the AWPAG (Appendix B) was performed at NWS Sterling, Virginia, and Johnstown, Pennsylvania, test sites to validate gauge compliance with performance requirements. The qualification testing demonstrated the AWPAGs met NWS hourly requirements, but did not always meet the event requirements due to under-reporting. New gauge firmware tested at Sterling and Johnstown during Summer 2003 has shown a significant increase in event compliance. Through mid-August, event compliance for Sterling events was 93%; and for Johnstown events, compliance was 100%. The production AWPAGs installed and evaluated at the OAT sites during the last phase of the OAT were equipped with the improved firmware.

Conduct of the OAT

The OAT began on February 27, 2003, with the installation of the AWPAG at Macon (MCN), Georgia, using the upgraded processor and ACU software V2.7B-1 (02/04/03). A total of 16 field sites participated in the OAT, 13 as “dual sensor sites” (AWPAG configured as the operational precipitation gauge and the HTBRG as a test gauge):

ABE	Allentown, PA	installed	05/14/03
ABR	Aberdeen, SD		04/01/03
AMA	Amarillo, TX		04/24/03
AVP	Wilkes-Barre, PA		04/03/03
BOI	Boise, ID		04/03/03
ERI	Erie, PA		03/12/03
GRB	Green Bay, WI		04/23/03
LAN	Lansing, MI		04/14/03
MCN	Macon, GA		02/27/03
MOB	Mobile, AL		05/12/03
PWM	Portland, ME		04/15/03

SPI	Springfield, IL	03/03/03
TRI	Bristol, TN	04/02/03

and three participated as "single sensor" sites (AWPAG configured as the operational precipitation sensor):

BOS	Boston, MA	installed	09/30/03
FCA	Kalispell, MT		09/24/03
MKG	Muskegon, MI		08/15/03.

Five different ACU processor software versions:

V2.7B-1 (dated 02/04/03)
V2.7B-3 (dated 03/20/03)
V2.7B-4 (dated 05/21/03)
V2.7B-5 (dated 06/30/03)
V2.7B-6 (dated 08/15/03)

were used at various times during the OAT as software problems, unrelated to the AWPAG, were documented and fixed. Throughout the OAT, AWPAG performance was not affected by the changes in ACU software versions.

Weekly OAT Test Review Group (TRG) conference calls were conducted to report the status of the OAT and to adjudicate problems. Minutes of these conference calls are available from the Office of Operational Systems, Field Systems Operations Center, Test & Evaluation Branch (OPS24).

The OAT was completed on June 3, 2004.

OAT Results

As stated in the OAT plan (Part II, Section 3), the following items were evaluated during the AWPAG OAT with results as noted:

installation procedures as documented in Draft Engineering Modification Note (Mod Note) 78 and any other instructions provided to the electronics technician (ET) or on-site staff:

The Program Management Branch (OST11) provided a Draft Mod Note for use by ETs during the installation of AWPAGs at the OAT sites. Revisions were incorporated based on OAT installation experience and the revised draft was forwarded to the Maintenance Branch (OPS12). The AWPAG Modification Note (#78A) is now posted on the ASOS Technician web page.

operator documentation (Release Note):
No problems were reported with the Draft Release Note (dated February 26, 2003) which was available during the OAT. The final Release Note is posted on the OPS22 implementation website:

http://www.nws.noaa.gov/ops2/surface/implementation.htm

Suitability of the ASOS Planned Product Improvement **Operational Implementation Checklist** – Part B:

The implementation checklist was judged satisfactory.

ASOS stability (with the AWPAG and V2.7B installed):

With V2.7B-6 and the AWPAG installed at the OAT sites, ASOS stability was slightly improved (as measured by the frequency of software crashes and warm starts) compared to the previous processor and V2.60 software. The processor upgrade (with ACU V2.7B-6) was approved for general distribution on December 4, 2003.

basic ASOS functionality (observation and product generation/transmission, operation of interfaces, etc.) of ASOS with the AWPAG installed:

With ACU V2.7B-6 and the AWPAG installed at the OAT sites, production, transmission, and archival of observations was judged satisfactory. No problems were noted with interfaces for the Advanced Weather Interactive Processing System (AWIPS), FAA AWOS/ASOS Data Acquisition System (ADAS), Automated Lightning Detection and Reporting System (ALDARS), ASOS Controller Equipment (ACE), Runway Visual Range (RVR), Next Generation RVR (NGRVR), or Ground-To-Air (GTA) radio.

Two issues of note were:

In August 2003, investigation of false precipitation accumulation reports at MOB determined several frogs had taken up residence in/around the weighing mechanism. After the frogs were removed, there were no more reports of false accumulation. The Engineering and Acquisition Branch (OPS11) is developing and evaluating solutions to the wildlife intrusion problem.

Although several sites reported smaller than expected liquid water equivalent amounts from snow in windy conditions, performance of the AWPAG was significantly improved over the HTBRG. Transfer functions which use wind and temperature data to correct the water equivalent amounts are being defined by the Development Branch (OST32) and will be available for preliminary evaluation

during Winter 2004-2005. Evaluation will be manual since the transfer functions cannot be incorporated into a new software version by Winter 2004-2005.

The performance evaluation of the OAT sites was completed in August 2003, but the OAT was extended to replace the pre-production OAT site AWPAGs with production units and to finalize environmental qualification test results, safety and environmental requirements, and maintenance procedures. By the end of the OAT, production AWPAGs replaced the pre-production units at all of the OAT sites and more than 10 satisfactory precipitation events (the approval criteria established by the OAT TRG) was documented.

Conclusions and Recommendation

AWPAG installation procedures (Mod Note 78), operator documentation (Release Note), and the Operational Implementation Checklist (Part B) were judged satisfactory by the ETs, observers, and the OAT Site Focal Points. ASOS stability (with the AWPAG and V2.7B ACU software) was slightly improved over stability with the previous processor (with V2.60 ACU software and the HTBRG). ASOS functionality (production, transmission, and archival of observations as well as support of all ASOS interfaces) was judged satisfactory by the OAT participants.

Based on the performance of the AWPAG and ACU V2.7B-6 during the OAT, the TRG recommended operational deployment of the AWPAG.

AWPAG Operational Acceptance Test Results

1. Background

Early in 2003, the ASOS PI support contractor was given the task to compare the Ott All-Weather Precipitation Accumulation Gauge (AWPAG) with the Frise Heated Tipping Bucket (HTB). The Ott gauge was selected by the ASOS program to replace the HTB at operational ASOS sites. The objective of the comparison was to determine operational comparability during liquid precipitation events. The comparison was mostly conducted during periods of time when the HTB heaters were not active. From previous winter testing experience with AWPAG/HTB comparisons, we would expect the HTB to significantly under-report when compared to the AWPAG during freezing and frozen precipitation events.

2. Scope of Test

Eleven Operational Acceptance Test (OAT) sites were selected for the study: Macon, Ga; Amarillo, TX; Mobile, AL; Bristol, TN; Boise, ID; Portland, ME; Wilkes-Barre, PA; Springfield, IL; Lansing, MI; Aberdeen, SD; and Green Bay, WI. The study involved the analysis of selected liquid precipitation events which occurred between March 6, 2003 and August 1, 2003. All AWPAGs were operated with firmware version 3.55 for the duration of the comparison.

3. Test Metrics

Two test parameters were monitored during the comparison: the absolute difference between the AWPAG and HTB, and the standard deviation of event differences.

4. Data Set

Total Accumulation and Difference in Inches				
03/06/03 - 08/01/03				
Site	Minutes	AWPAG	HTB	Difference
KABR	1646	5.34	5.3	0.04
KAMA	1681	4.68	4.76	-0.08
KAVP	12264	15.31	13.81	1.5
KBOI	4138	2.1	2.28	-0.18
KGRB	6431	5.22	5.38	-0.16
KLAN	4710	6.63	6.5	0.13
KMCN	9135	25.12	24.68	0.44
KPWM	12171	8.16	7.81	0.35
KSPI	7272	12.4	12.43	-0.03
KTRI	11536	22.27	21.92	0.35
Total	70984	107.23	104.87	2.36

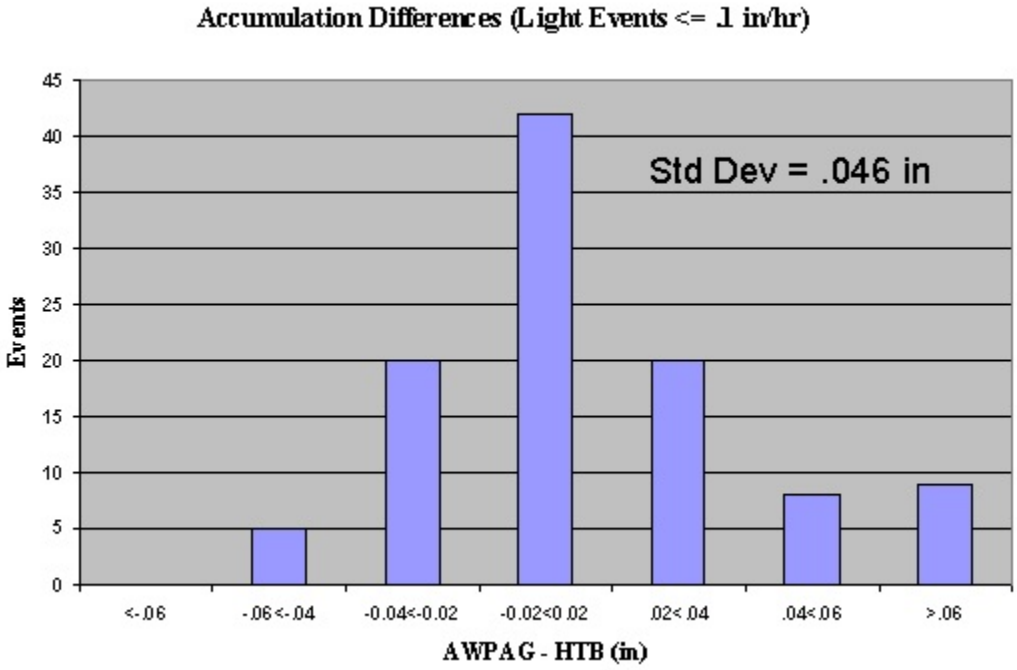
Notes:

(1) KABR - Aberdeen AWPAG was initially installed without a wind shield and showed a significant delta in gauge catch efficiency. The catch efficiency improved markedly after the Tretyakov shield was installed. The data set for KABR is limited to information gathered after the shield was installed.
(2) KAMA - Amarillo AWPAG heater controller board was defective and was replaced. Data set is limited to data gathered after the board was replaced.
(3) KMOB - Mobile AWPAG reported numerous indications of false precipitation. The gauge failed to meet the contractual specifications for false reports and was therefore not included in the final analysis.

5. Results

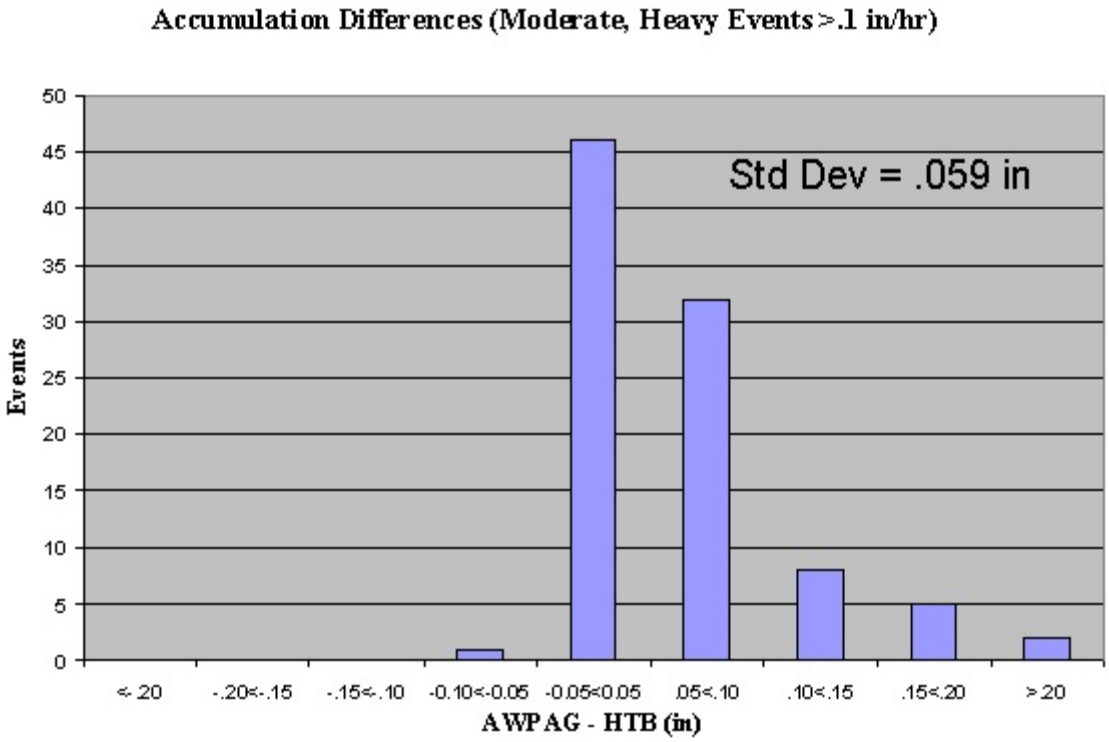
A total of approximately 71,000 minutes of liquid precipitation were analyzed. Considering all events at all ASOS sites, the AWPAG reported 2.2% more precipitation than the HTB (107.23 inches vs 104.87 inches).

The comparison included 106 light rain events covering nearly 53,000 minutes of data. During these light rain events, there was a negligible difference between the AWPAG and the HTB. The results of the analysis for light rain events is shown in the following graph:



The comparison also included 94 cases of moderate and heavy liquid precipitation events totaling nearly 18,000 minutes of data. During moderate and heavy rain events, the AWPAG reports a slightly higher accumulation than the HTB, as shown in the following graph:

6. Conclusions/Recommendations:



(a) Overall performance of the AWPAG is comparable to the HTB, showing only a 2% increase in reported precipitation accumulation.

(b) On an individual event basis, the HTB fell increasingly behind the accumulation reported by the AWPAG. This was thought to be caused by weak HTB batteries due to aging. However, maintenance information did not support that theory.

(c) The AWPAG gauge should always be installed with the recommended Tretyakov wind shield.

(d) The gauge at Mobile exhibited many false precipitation reports. The gauge was found to have several small frogs inside the gauge housing which may have been the cause of the false reports. The gauge manufacturer and Government should continue to seek ways to prevent wildlife intrusion.

(e) Mobile AWPAG reports will continue to be monitored for false precipitation accumulation. No false reports were noted during the period 9/6/03 - 9/16/03. Additional data are currently being analyzed.

(f) The Government has developed a precipitation accumulation validation algorithm that is slated for implementation in ASOS ACU V2.80 firmware. That logic will remove false precipitation accumulation reports, preventing them from being included in subsequent METARs, SPECIs, and climatological reports. The implementation of the algorithm will greatly reduce the workload associated with the manual removal of erroneous data.

FINAL REPORT FOR

WINTER TEST OF PRE-PRODUCTION
ALL-WEATHER PRECIPITATION ACCUMULATION GAUGE (AWPAG)

SEPTEMBER, 2002 - APRIL, 2003

Version 7
August 22, 2003

Prepared for

National Weather Service OST32

by

These data are furnished for technical information only. The National Oceanic and Atmospheric Administration does not approve, recommend, or endorse any product; and the test and evaluation results should not be used in advertising, sales promotion, or to indicate in any manner, either implicitly or explicitly, endorsement of the product by the National Oceanic and Atmospheric Administration.

EXECUTIVE SUMMARY

Background

The Frise heated tipping bucket is the standard liquid precipitation accumulation gauge used with the Automated Surface Observing System (ASOS). The sensor measures liquid accumulation, but is not specifically designed to accurately measure freezing or frozen precipitation. The accurate measurement of liquid equivalent accumulations in all types of liquid, solid, and mixed precipitation is an important part of weather observations. The National Weather Service (NWS) ASOS Product Improvement (PI) team has conducted testing of all-weather precipitation accumulation gauges (AWPAG) since 1996.

A contract for design and development of ten pre-production gauges was awarded on September 25, 2001, to C.C. Lynch and Associates (CCLA) of Pass Christian, Mississippi, in partnership with Ott Hydrometry of Kempten, Germany. In January 2002, CCLA delivered four prototype gauges that included the most significant proposed performance modifications. Testing of these four gauges during 2002 demonstrated improvements in gauge catch, accuracy, increased capacity, and communications. The results were reported in the *Interim Report for Ott AWPAGs, January, 2003*.

Qualification testing of gauges was conducted during the winter of 2002-2003, at the Sterling Virginia and Johnstown Pennsylvania test sites to validate gauge compliance with performance requirements. In addition to the four retrofitted prototype gauges, two limited production AWPAGs were acquired in January 2003, to replace one retrofitted prototype gauge at each of the test sites in Sterling and Johnstown.

Ott firmware version 3.49 was installed in the gauges at Sterling and Johnstown in September, 2002. Later firmware versions contained little or no changes in the internal gauge reporting algorithms and were developed specifically for ASOS maintenance enhancements. Because of the minimal impact on precipitation measurement performance with versions 3.52 to 3.54, the PI staff decided to use data collected with versions 3.49 to 3.54, as the basis for this report.

Results

The results of the hourly comparisons show that the Ott AWPAGs were within the NWS accuracy requirements nearly 100% of the time. A total of 430 hourly observations was taken, with 303 of these classified as frozen or mixed precipitation and 127 as liquid precipitation. One AWPAG at Johnstown (#085), was 0.03 inches low (0.02 vs 0.05) on one hourly observation. The other AWPAG at Johnstown (#087) was non-compliant for one hourly comparison because of under-reporting by 0.03 inches (0.03 vs 0.06).

Fifty (50) events were evaluated in this test comprising a total of 100 AWPAG comparisons. Of these 100 comparisons, 76% of the AWPAG event totals met the NWS AWPAG reporting requirements. The gauges did not over-report, but were non-compliant 24% of the time because of under-reporting. The amount of under-reporting averaged 3.5 to 4.5% among the AWPAGs. Overall, the comparison ASOS Frise gauges met the same requirements for event totals only 52% of the time during the test and under-reported by an average of 9.5 to 25%.

The AWPAGs met the requirements for false reports 100% of the time. A limited production gauge was installed at Johnstown during a very cold, blowing snow event. For 10 days after installation, this gauge exhibited a tendency to report false accumulations; but after a thawing period in early February 2003, the gauge met the requirements for false reports in the remainder of the test. Snow and ice had apparently intruded into a critical area of the weighing mechanism during installation. This indicates that installation and maintenance of AWPAGs should only be performed in fair weather conditions.

One up-graded prototype gauge at Johnstown suffered a temperature sensor failure in February 2003. The sensor reported an increasing cold bias until it was replaced on February 27, 2003.

Spot weld failures occurred on the outer shell (pipehouse) of two prototype AWPAGs: one at Sterling and one at Johnstown.

One limited production AWPAG that was not part of the specification compliance test, failed the operational acceptance test at Sterling because of false reports of precipitation. An unusual diurnal pattern in the raw and filtered weight values was produced from the gauge that closely matched the ambient temperature changes in the test bed. The gauge was removed from the test bed and was returned to the manufacturer.

Conclusions

Testing has shown that the AWPAGs can meet the NWS hourly requirements, but not always meet the event requirements due to under-reporting. The AWPAGs performed well in moderate to heavy precipitation events. Firmware modifications to the internal gauge reporting algorithms are required to provide improvement in gauge performance during light precipitation events.**

The AWPAGs tested without shields revealed an increased loss of precipitation catch, even in liquid events, when compared against shielded AWPAGs and shielded 8-inch reference gauges in increased winds, apparently due to the size and aerodynamics of the AWPAGs. Due to reduced catch efficiency of unshielded AWPAGs, it is recommended that windshields be provided for all installed AWPAGs.

** Gauge firmware version 3.58 has been under test at Sterling and Johnstown during Summer 2003 and has shown a significant increase in event compliance. Through mid-August, event compliance for Sterling events was 93%; and for Johnstown events, compliance was 100%.